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Prevalence of Respiratory Symptoms and Diseases in Schoolchildren Living in a Polluted and in a Low Polluted Area in Israel[1]

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Second and fifth grade schoolchildren living in two communities with different levels of air pollution were studied. The parents of these children filled out ATS–NHLI health questionnaires. The prevalence of reported respiratory symptoms and pulmonary diseases was found to be significantly higher among children growing up in the polluted community (Ashdod) as compared with the low-pollution area (Hadera). Logistic models fitted for the respiratory conditions which differed significantly between both areas of residence also included background variables that could be responsible for these differences. Relative risk values, which were calculated from the logistic models, were in the range of 1.47 for cough without cold to 2.66 for asthma for children from Ashdod, as compared with 1.00 for children from Hadera.

INTRODUCTION

It is well known that high air pollution concentrations may influence morbidity and mortality from respiratory conditions. However, the health impact of long-term exposure to low concentrations of air pollutants is not fully known. Many surveys have been carried out during the last decades in an effort to detect possible health effects resulting from long-term exposure to low concentrations of air pollution. In these surveys, which were mainly carried out among adults, it was demonstrated that factors such as smoking and occupational exposure are correlated with the incidence and prevalence of respiratory conditions (Colley and Holland, 1967; Colley *et al.*, 1973; Goldsmith and Friberg, 1977; Holland *et al.*, 1969a; Irvine *et al.*, 1980). Since the effects of air pollution on the respiratory tract are relatively low as compared with those of smoking, controlling for such factors in the analysis is crucial.

Many surveys have recently been conducted among young children who are not occupationally exposed and do not smoke (Biersteker and Leeuwen, 1970; Colley and Brasser, 1980; Colley and Reid, 1970; Ferris, 1978a; Goren and Goldsmith, 1986; Holma *et al.*, 1979; Irvine *et al.*, 1980; Lunn *et al.*, 1967; Melia *et al.*, 1981; Mostardi *et al.*, 1981a; Mostardi *et al.*, 1981b; Toyama, 1964).

However, many variables other than smoking and occupational exposure may affect the respiratory system in the same direction as air pollution and should therefore be taken into account in the analysis. Such variables are socioeconomic

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status (Colley and Reid. 1970: Goren and Goldsmith. 1986: Holland *et al.*, 1969a. b: Melia *et al.*, 1981: Peat *et al.*, 1980). crowding index (Holma *et al.*, 1979: Leeder *et al.*, 1976: Lunn *et al.*, 1967: Peat *et al.*, 1980). type of fuel used in household (Hasselblad *et al.*, 1981). smoking habits of adults at home (Bland *et al.*, 1978: Cameron *et al.*, 1969: Colley. 1974: Fergusson *et al.*, 1980: Fergusson *et al.*, 1981: Goren and Goldsmith. 1986: Hasselblad *et al.*, 1981: Lebowitz and Burrows. 1976: Leeder *et al.*, 1976: Schilling *et al.*, 1977: Tager *et al.*, 1979: Vedal *et al.*, 1984: Ware *et al.*, 1984). and respiratory diseases among family members of the observed children (Colley. 1974: Goren and Goldsmith. 1986: Higgins and Keller. 1975: Leeder *et al.*, 1976: Schilling *et al.*, 1977: Tager *et al.*, 1978). This work was carried out in order to compare the health status of children growing up in a polluted area with that of children in a clean one. taking into account all the above-mentioned factors. It was assumed that children growing up in a region with elevated sulfur dioxide concentrations suffer from more respiratory symptoms and diseases as compared with children growing up in a clean area.

MATERIALS AND METHODS

This survey was carried out among schoolchildren from two communities located along the Israeli coast 80 km from each other. but differentially exposed to air pollution. One group lives in Ashdod (Fig. 1). which is an industrialized town. mainly polluted by an 1100-MW oil-fired power station. refineries. and a complex industrial zone (which includes a herbicide factory and acrylic fiber and lead-melting plants). The population of this area numbers about 65.000 (the country of origin of their fathers: 32%. Europe-America: 49%. North Africa: 14%. Asia: and 5%. Israel). The second group lives in Hadera. which was an unpolluted area in 1980 (when this survey was carried out). These baseline health data in Hadera were gathered in the framework of a prospective epidemiological monitoring program carried out in this area since a new 1400-MW coal-fired power plant was to begin operating there in 1982 (Toeplitz *et al.*, 1984). The population of this area numbers about 76.000 persons (the country of origin of their fathers: 39%. Europe-America: 28%. North Africa: 19%. Asia: and 14%. Israel).

Study population. Second and fifth grade pupils from 24 schools in Hadera and surroundings (a low-pollution area) were studied in 1980. In 1982 second and fifth grade pupils from 15 schools in Ashdod and surroundings (a polluted area) were surveyed.

Health questionnaire. The health questionnaire (Ferris. 1978b) used in this study is a translation into Hebrew of the ATS-NHLI (American Thoracic Society and the National Heart and Lung Institute) health questionnaire to be self-administered by the children's parents. The questionnaires were distributed in both communities between March and June by the school nurse. who also collected them after they had been filled out. From the health questionnaires the following information was obtained: respiratory symptoms and diseases of the children. socioeconomic status. type of household fuel used. smoking habits of the parents. respiratory problems in the families.

Of the 1984 questionnaires distributed in the Hadera area. 1702 were returned —a response rate of 85.8%. In Ashdod. 1826 questionnaires were distributed and 1672 were filled out—a response rate of 91.6%. In both areas. almost all the

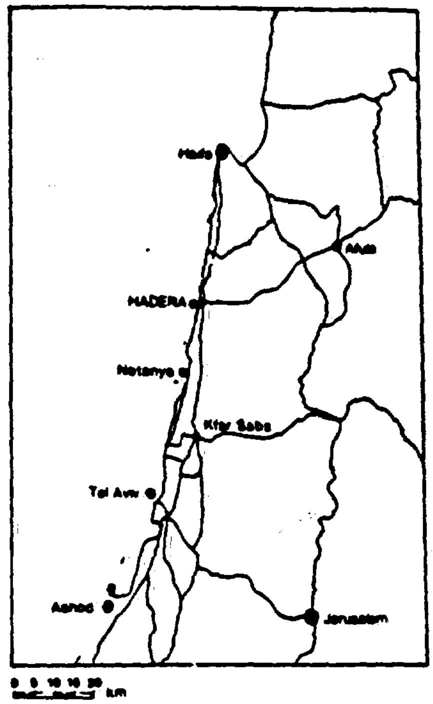

FIG. 1. Site of the two communities Hadera (nonpolluted) and Ashdod (polluted).

children of the studied cohorts living in the community for at least 5 years were examined.

Air pollution measurements. Air pollution measurements are carried out in the Hadera area by the local municipal authorities and in the Ashdod area by the electric company. The monitoring stations in the Hadera area (low pollution) are fully automatic and measure SO_2, NO, NO_2, NO_x, total hydrocarbons, O_3, CO, TSP, and various atmospheric parameters (such as temperature and humidity). SO_2 is measured by means of a flame photometric instrument, and NO_x by a chemiluminescent apparatus.

The monitoring stations in the Ashdod area (polluted) are automatic and measure SO_2, NO_x, soiling index, and meteorological parameters. SO_2 is measured by means of a conductometric instrument and NO_x by a chemiluminescent apparatus.

Analytic procedure. Statistical analysis of the data was carried out by means of the SPSS program (Nie *et al*., 1975). Prevalence of respiratory symptoms and diseases according to place of residence was analyzed by means of the χ^2 test for examination of independence between two variables. The possible effect of a different distribution of background variables in both areas of residence was examined by stratification.

In order to examine the combined effect of all variables in each area, a non-

hierarchical logistic model (Dixon *et al.*, 1981) was fitted for the frequency of each respiratory symptom or disease. Those background variables which were included in the logistic regression for each population and the areas of residence were included in the logistic model fitted for the respiratory condition in the pooled data set of both populations. The equation for the predicted proportion of the respiratory condition $E(\frac{f}{n})$ according to the logistic regression is $E(\frac{f}{n}) = e^u/1 + e^u$ in which f is the frequency of the respiratory condition. n is the sample size. $u = \alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots \beta_m x_m$. in which $x_1, x_2 \ldots x_m$ are the background (binary) variables and $\alpha, \beta_1, \beta_2 \ldots \beta_m$ are the coefficients.

The logistic regression estimates the coefficients of the background variables (such as father's country of origin, crowding index, type of household fuel used, smoking habits of parents, and respiratory diseases among children's fathers) in a stepwise manner.

The relative risk (*RR*) to suffer from a respiratory condition in the polluted community as compared with the low-pollution community was calculated from the logistic regression as follows: $RR = e^{\beta_1}$ where β_1 is the coefficient of the area of residence.

RESULTS

SO_2 concentrations—both monthly averages and maximal half-hourly concentrations—are much higher in Ashdod than in Hadera. The same holds for NO_x concentrations in both areas (Table 1).

The frequency of reported respiratory symptoms (Fig. 2) among schoolchildren from Ashdod, the polluted area, is higher than among children growing up in the

TABLE 1

MONTHLY AVERAGES AND MAXIMAL HALF-HOURLY CONCENTRATIONS OF SULFUR DIOXIDES (IN $\mu g\ m^3$) AND NO_x (IN ppb) IN ASHDOD (POLLUTED AREA) AND IN HADERA (LOW POLLUTED AREA) IN 1982

	Hadera				Ashdod			
	SO_2 ($\mu g\ m^3$)		NO_x (ppb)		SO_2 ($\mu g/m^3$)		NO_x (ppb)	
Month	Monthly average	Maximal ½ hr	Monthly average	Maximal ½ hr	Monthly average	Maximal ½ hr	Monthly average	Maximal ½ hr
January	7.0	416	7.7	53	27.7	276	32.3	528
February	7.0	99	6.9	37	42.4	402	7.7*	38
March	6.5	179	8.4	76	22.7	493	13.3	43
April	6.2	146	8.2	57	40.6	670	19.8	127
May	5.2*	169	10.2*	94	45.2	836	32.3	176
June	3.1	135	8.0	95	18.1	415	7.9	69
July	2.6	68	7.3	128	10.6	309	11.3	76
August	1.0	18	6.4	60	18.1	133	11.6	97
September	4.7	140	7.5	64	21.1	417	19.3	63
October	3.4*	166	6.2*	39	28.6	451	17.6	74
November	2.1*	203	6.9*	71	33.0	295	14.8*	78
December	1.8	62	7.0	48	30.4	595	33.3*	200

* Data availability less than 50%.

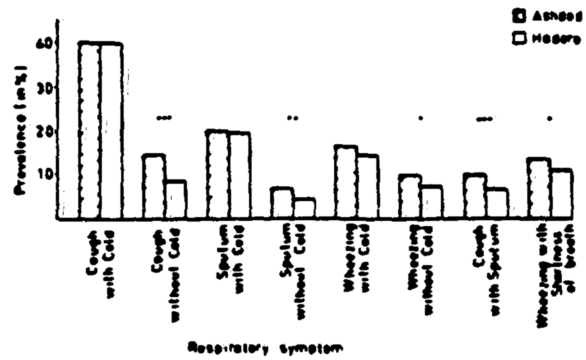

FIG. 2. Prevalence of respiratory symptoms (in %) among second and fifth grade school children from Ashdod (polluted area) and from Hadera (nonpolluted area). *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

nonpolluted area (Hadera). Cough without cold. sputum without cold. wheezing without cold. attacks of cough with sputum. and wheezing accompanied by shortness of breath are significantly more common among Ashdod children. It should be emphasized that transient respiratory symptoms. namely. cough with cold. sputum with cold. and wheezing with cold. are not significantly more common among children from the polluted area.

Figure 3 summarizes the frequency of reported respiratory diseases (in %) in second and fifth grade schoolchildren in Ashdod and Hadera. Chest illnesses that kept children from their usual activities. chest illnesses with sputum production. number of such illnesses. pneumonia. bronchitis. and asthma are significantly more prevalent among children growing up in Ashdod. On the other hand. illnesses such as measles. sinus trouble. ear infections and allergy are not significantly more common among Ashdod children. Analysis of background variables which may influence the prevalence of respiratory conditions of the children shows that children in Ashdod grow up in more crowded homes. in fewer houses

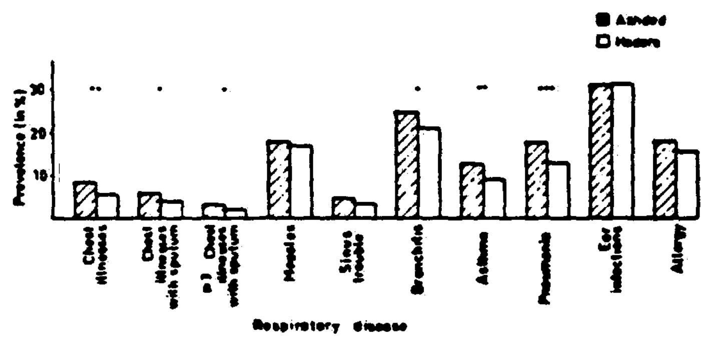

FIG. 3. Prevalence of respiratory diseases (in %) among second and fifth grade school children from Ashdod (polluted area) and from Hadera (nonpolluted area). *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

with heat, their fathers report more respiratory problems, and their fathers are more frequently from oriental countries, as compared with children from Hadera (Table 2). The effect of these background variables on the prevalence of respiratory problems among Ashdod children was controlled for in further analytic procedures.

It could be shown, by stratification, that the different prevalence of respiratory symptoms and diseases among children from Ashdod and Hadera remains consistent (although not always statistically significant) within the subgroups of background variables. For instance, among children whose houses are heated (Table 3), the prevalence of respiratory symptoms and diseases is higher in Ashdod children than in Hadera children; the difference is statistically significant for most symptoms and diseases.

The logistic models fitted for the respiratory conditions which differed significantly between both areas of residence enabled a calculation of the relative risk to suffer from a respiratory condition in Ashdod as compared with Hadera. Most of the models fitted included the area of residence as a significant component (Table 4). All the models included some background variables, especially respiratory conditions of the fathers.

Most of the models fitted for respiratory conditions demonstrate well the interactions between the respiratory conditions and the background variables.

The relative risks calculated for respiratory conditions in Ashdod are between 1.47 for cough without cold and 2.66 for asthma, as compared with 1.00 for Hadera children.

DISCUSSION

Our results are in accord with findings in the literature, which indicates a higher prevalence of respiratory symptoms and diseases among children growing up in polluted as compared with nonpolluted areas. The WHO collaborative study on the relationship between air pollution and respiratory diseases in chil-

TABLE 2
FREQUENCY (IN %) OF BACKGROUND VARIABLES AMONG SECOND AND FIFTH GRADE SCHOOLCHILDREN FROM ASHDOD (POLLUTED AREA) AND HADERA (NONPOLLUTED AREA)

Background variable	Frequency in Hadera (%)	Frequency in Ashdod (%)	P value
Crowding index (≥1.5 persons/room)	56.0 (1738)[a]	61.3 (1368)	0.003
No heating	12.6 (1791)	24.0 (1450)	<0.001
Father's education (≤8 years)	29.7 (1682)	27.3 (1304)	N.S.(0.168)[b]
Mother smoking	21.6 (1744)	16.1 (1391)	<0.001
Respiratory diseases among fathers	8.3 (1557)	10.8 (1162)	0.034
Oriental origin of father	52.5 (1775)	68.2 (1420)	<0.001

[a] Number of children in parentheses.
[b] $P > 0.05$ is considered as N.S.

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TABLE 3
PREVALENCE (IN %) OF RESPIRATORY SYMPTOMS AND DISEASES AMONG SECOND AND FIFTH GRADE SCHOOLCHILDREN FROM ASHDOD (POLLUTED AREA) AND HADERA (NONPOLLUTED AREA) WITHIN THE SUBGROUP OF CHILDREN WHOSE HOUSES ARE HEATED

Respiratory symptom or disease	Prevalence in Hadera (%)	Prevalence in Ashdod (%)	P value
Cough with cold	39.9 (1536)*	40.1 (1080)	N.S.(0.957)*
Cough without cold	8.2 (1530)	14.8 (1075)	<0.001
Sputum with cold	19.1 (1485)	20.8 (1050)	N.S.(0.333)
Sputum without cold	3.9 (1481)	6.9 (1038)	0.001
Wheezing with cold	14.0 (1426)	17.0 (997)	0.050
Wheezing without cold	7.1 (1245)	9.8 (936)	0.030
Cough + sputum	6.3 (1423)	10.1 (1009)	<0.001
Wheezing with shortness of breath	10.6 (1467)	13.6 (1029)	0.028
Chest illnesses	5.8 (1509)	9.5 (1051)	<0.001
Chest illness with sputum	4.5 (1398)	7.8 (1020)	<0.001
Three or more illnesses with sputum	2.4 (1404)	4.5 (1006)	0.005
Measles	16.4 (1292)	17.5 (888)	N.S.(0.560)
Sinus trouble	4.9 (1248)	3.7 (859)	N.S.(0.243)
Bronchitis	22.0 (1325)	25.4 (903)	N.S.(0.070)
Asthma	9.8 (1261)	13.0 (868)	0.026
Pneumonia	12.9 (1307)	18.1 (901)	0.001
Ear infections	31.7 (1304)	32.6 (868)	N.S.(0.683)
Allergy	15.9 (1493)	19.1 (1018)	0.043

* Number of children in parentheses.
* $P > 0.05$ is considered as N.S.

dren (Colley and Brasser, 1980) showed a close association between air pollution and various respiratory indices in children. The Groupe Cooperatif PAARC (1982) also demonstrated that children growing up in SO_2-polluted areas in France show a higher prevalence of upper respiratory symptoms.

TABLE 4
RELATIVE RISK FOR RESPIRATORY SYMPTOMS AND DISEASES FOR SECOND AND FIFTH GRADE SCHOOLCHILDREN FROM ASHDOD (POLLUTED AREA) AS COMPARED TO HADERA (NONPOLLUTED AREA)

Respiratory symptom or disease	Hadera	Ashdod	P value (for area)
Cough without cold	1.00	1.47	0.049
Cough + sputum*	1.00	1.55	0.007
Chest illnesses	1.00	1.95	0.003
Chest illnesses + sputum	1.00	1.91	0.015
Bronchitis*	1.00	2.30	0.008
Asthma	1.00	2.66	0.039
Pneumonia	1.00	1.47	0.003
Respiratory diseases among siblings	1.00	1.54	0.002

* The model does not fit very well (P value for model <0.1).

Other cross-sectional surveys carried out among schoolchildren in different countries also showed an association between area of residence and prevalence of upper and lower respiratory tract illnesses (Colley and Holland, 1967; French *et al.*, 1973; Hammer *et al.*, 1976; Love *et al.*, 1981; Lunn *et al.*, 1967; Melia *et al.*, 1981; Mostardi *et al.*, 1981b; Toyama, 1964).

Ferris (1978a), in a review article, criticized most children studies, especially because of insufficient control of possible confounding factors, and because exposures for children were only estimated.

Lebowitz (1981) recommends spatiotemporal designs as useful strategies in surveillance of respiratory effects of point sources of pollution. In this study, we tried to estimate health effects in two communities with different pollution levels. We used a spatial approach in which multivariate statistical analyses were performed in order to control for possible confounding factors. As in other environmental studies, only estimates of exposure for children, based on community monitoring, were available.

Monthly average concentrations of SO_2 in Ashdod are within the range of 10.6 and 45.2 $\mu g/m^3$, with an annual average of about 30 $\mu g/m^3$.

In their study, Love *et al.* (1981) demonstrated health effects among schoolchildren with air pollution levels similar to those measured in our study. Melia *et al.* (1981) could not show any relation between prevalence of respiratory illness and SO_2 annual means ranging from 12 to 114 $\mu g/m^3$. Other studies (French *et al.*, 1973; Groupe Cooperatif PAARC, 1982; Hammer *et al.*, 1976; Mostardi *et al.*, 1981b) indicate higher SO_2 concentrations as threshold levels for aggravation of respiratory conditions.

It is possible that other pollutants, either separately or in combination with SO_2 and NO_x, contribute to the observed health effects. Since no measurements of the concentrations of heavy metals and organics (herbicides, for example) are carried out in Ashdod, their contribution to the health status of the population is not known.

In our survey, we could show that chronic respiratory symptoms, and most pulmonary diseases, were significantly more common among children from the polluted area. The higher prevalence of only the chronic (and not the transient) respiratory symptoms can not be attributed to general tendency of the population in Ashdod to overreport respiratory conditions among their children.

It is of interest that the logistic models fitted for the respiratory conditions better demonstrate the interaction between the background variables and the respiratory diseases, rather than the interaction with respiratory symptoms. The relative risks calculated for respiratory symptoms in Ashdod children were found to be about 1.50, and those for pulmonary diseases within the range of 1.47 and 2.66, as compared with 1.00 for Hadera children.

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